Energy, Mines and Resources Canada | Énergie, Mines et Ressources Canada

CANMET

Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

MEASUREMENT OF IN SITU STRATA GAS PRESSURE AT NO. 26 COLLIERY, SYDNEY COALFIELD, N.S.

W.D. Gallant and T.R.C. Aston
Cape Breton Coal Research Laboratory

January 1985

This document is an unedited interim report prepared [illegible] to [illegible] and does not necessarily represent final expression of the opinion of the Canada Centre for Mineral and Energy Technology (CANMET)

Ce document est un rapport provisoire non révisé et rédigé [illegible] pour fin de [illegible] de documentation [illegible] ne représente nulle[illegible] expression définitive de [illegible] du Centre canadien de la technologie des minéraux et de l'énergie (CANMET)

MICROMEDIA
JUL 03 1985

22 pp

ENERGY RESEARCH PROGRAM
COAL RESEARCH LABORATORIES
DIVISION REPORT ERP/CRL 85-10(TR)

MEASUREMENT OF IN SITU STRATA GAS PRESSURE AT NO. 26 COLLIERY, SYDNEY COALFIELD, N.S.

by

W.D. Gallant* and T.R.C. Aston**

SUMMARY

In late 1983 and early 1984 a series of outbursts resulted in the temporary cessation of further development of the No. 26 main deeps drive-ages. The outbursts were accompanied by the rapid release of methane, which could not be accounted for by the strata properties of permeability and porosity. An elevated gas pressure within the strata prone to outburst was therefore postulated. This report describes the methodology adopted to measure the in situ strata gas pressure as well as the equipment, installation procedures and results.

---

*Technologist and **Research Scientist, Cape Breton Coal Research Laboratory, CRL, CANMET, Energy, Mines and Resources Canada, Sydney.

MESURE DE LA PRESSION DE GAZ IN SITU À L'INTÉRIEUR DES STRATES À LA HOUILLÈRE N° 6 DU BASSIN HOUILLER DE SYDNEY, N.-É.

par

W.D. Gallant* et T.R.C. Aston**

RÉSUMÉ

À la fin de l'année 1983 et au début de l'année 1984, une série d'explosions à mis fin temporairement aux travaux de creusage de la fosse principale à la houillère n° 26. Les explosions étaient accompagnées d'un dégagement instantané de méthane qui restait sans explication en raison des caractéristiques de perméabilité et de porosité des strates. On a alors cru que la pression élevée de gaz à l'intérieur des strates avait pu provoquer les explosions. Le rapport présente une description des méthodes utilisées pour mesurer la pression de gaz à l'intérieur des strates ainsi que de l'équipement et des méthodes d'installation et fait part des résultats.

*Technologue et **Chercheur scientifique, Laboratoire de recherche sur le charbon du Cap-Breton, LRC, CANMET, Énergie, Mines et Ressources Canada, Sydney.

CONTENTS

	Page
SUMMARY	i
SOMMAIRE	ii
INTRODUCTION	1
METHODOLOGY AND EQUIPMENT	2
INSTALLATION AND TESTING	4
Underground Installation and Testing	7
Laboratory Testing of Packer System	9
TEST CAVITY - GAS ANALYSIS	11
DISCUSSION	13
CONCLUSION	14
ACKNOWLEGEMENTS	14
REFERENCES	14
APPENDIX A	15
APPENDIX B	17

FIGURES

No.		
1.	Borehole packer system	3
2.	Pressure loss along the line of contact between the seal and the strata	5
3.	Pressure loss through the intact wallrock surrounding the inflatable glands	5
4.	Pressure loss through fractures resulting in gas migration along both the seal-strata contact and through the surrounding wallwork	5
5.	Control box circuits for the packer system	6
6.	Location of packer test borehole, No. 26 colliery workings	8
7.	Test cavity pressure against time, No. 26 colliery borehole	10
8.	Test cavity pressure against time, laboratory testing of packer system	12

INTRODUCTION

At No. 26 Colliery since 1977, 37 outburst events of varying severity have been identified as occurring in the mine workings below a depth of 700 m. Many of the earlier events were initially recorded as roof falls because of their docile nature (1). However, as the depth of mining increased so too did the violence of the occurrences. On November 23, 1983 and January 6, 1984 outburst events damaged 16-18 and 15+ arches respectively. The January 6 occurrence ejected + 150 m^3 of material and resulted in the temporary cessation of further development of the No. 26 main deeps driveages.

Areas in the mine workings where the outbursts occurred are restricted to roadways below a depth of 700 m, where a sandstone horizon occurs within 3 m of the top of the coal and through which arched development is being driven using drill and blast techniques.

Most of the outburst events appear to have been accompanied by the rapid release of methane gas (1), although in the case of the earlier events it was not reported either because it was not looked for or simply because it did not exist. It should be noted that the last two events, November 23, 1983 and January 6, 1984 were accompanied by large emissions of methane, 753 m^3 and 3171 m^3 respectively. Initial porosity determinations on the sandstone unit indicate a porosity of about 5%, with permeability values in the range 0.01 to 0.05 md (millidarcies). These values cannot account for the observed quantities of gas released and a concept of pressurised gas contained within the strata (particularly the sandstone unit) was evolved (1). Gas desorption tests carried out on samples taken from the sandstone unit tend to support this hypothesis. A research programme was therefore undertaken by CBCRL to monitor and determine the in situ gas reservoir pressure of the methane contained within the sandstone. This report presents the methodology adopted, equipment and installation procedures and the results obtained.

METHODOLOGY AND EQUIPMENT

The method adopted to attempt the measurement of the in situ gas reservoir pressure of the strata was to seal off a length of borehole and measure the resultant build up in gas pressure in the sealed portion of the borehole, Figure 1. Gas migrates from a high pressure regime to a low pressure regime, with the flow rate dependent upon the magnitude of the pressure gradient and the porosity/permeability of the surrounding strata. The gas pressure in the sealed portion will therefore eventually reach some equilibrium with the in situ gas pressure in the strata.

Factors which are likely to effect the equilibrium pressure in the sealed length of the borehole are:

1. The distance from the sealed test section to the mine roadway/ opening.
2. The tightness of the 'seal to rock' contact.
3. The ability of the gas to migrate both into the test section and around the seals from the test section to the main body of the borehole.
4. The tightness of the pressure measuring equipment, transmission lines, couplings and fittings.
5. The in situ strata gas pressure.

It should be noted that gas migration occurs from strata surrounding a mine opening into the opening via a fracture/fissure network which is induced in the strata by the opening. To ensure that measurements are taken in strata which is undisturbed, it is necessary to install the packer arrangement a minimum distance of three tunnel diameters from the side of the roadway.

Potential pressure losses can be attributed to the less than total sealing of the test section between the seals. The line of contact between the seal and strata in the borehole may permit gas to pass across or around it therefore reducing the test section pressure. A series of conceptual pressure loss regimes can be envisaged around the test seals:

1. Pressure loss along the line of contact between the seal and the strata, Figure 2.
2. Pressure loss through the intact wallrock of the borehole from the test section into the main body of the borehole, Figure 3.

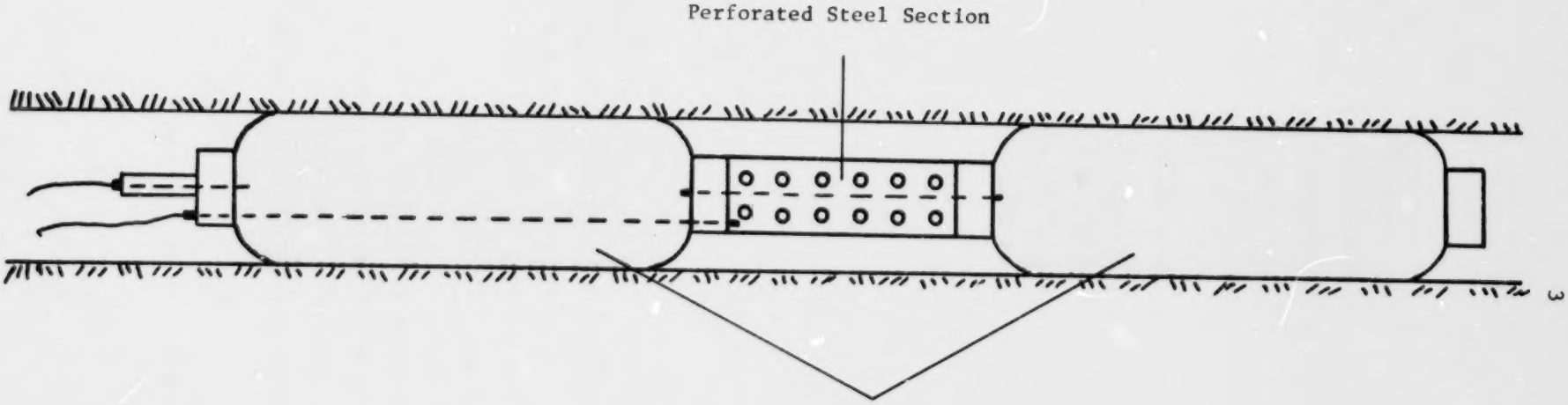

Figure 1 - Borehole packer system

3. Pressure loss through fractures induced in the strata during drilling which result in gas migration along both the seal-strata contract and through the wall work strata, Figure 4.

Once gas pressure in the borehole test section has stabilized, it is assumed that the pressure/flow regime around the section has reached equilibrium.

The packer system used was obtained from RocTest of Montreal and consisted of a Model VLP 40/60 designed to fit in a 75 mm diameter borehole. It consists of two inflatable rubber glands 1 m long separated by a 1 m long section of perforated steel tubing. The transmission lines consisted of two thick wall nylon tubes (2 mm ID and 6 mm OD), one connected to the rubber glands and the other to the perforated section via compression fittings.

The control box for the packer system contained two circuits, Figure 5:

1. The cavity (perforated section).
2. The inflatable rubber glands.

The circuits consist of a pressure gauge and valve system, where the valves have three operating positions:

1. Open to pressure supply.
2. Closed to pressure supply.
3. Open to exhaust.

Originally, either water or hydraulic fluid was to be used to inflate the glands because of its low compressability compared to a gas. However, because of the problems involved with the transportation and use of both media underground, it was decided to inflate the glands (packers) using a compressed gas source. Initially, compressed air was considered, but subsequently ruled out because of the likelihood of air-methane mixtures forming within the borehole. Nitrogen was therefore used because of its inert nature and ease of handling. The gas was transported underground using small 'Portaflam' cylinders containing a pressure of 15.2 MPa (2200 psi).

INSTALLATION AND TESTING

Two sets of RocTest VLP 40/60 packers were acquired by CBCRL. Initially, one set was used in the laboratory to familarise personnel with

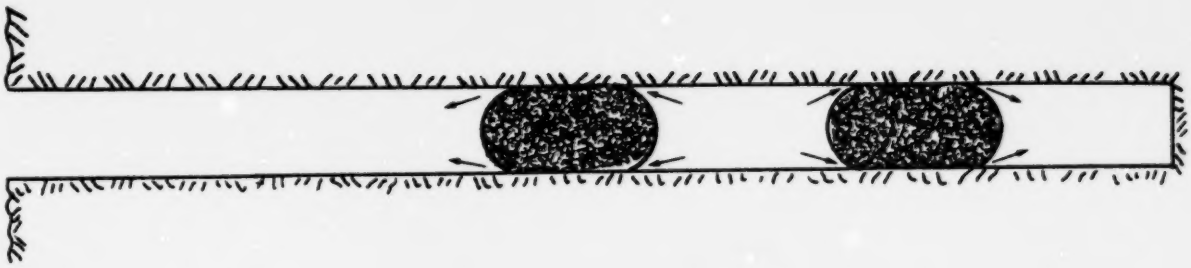

Figure 2 - Pressure loss along the line of contact between the seal and strata

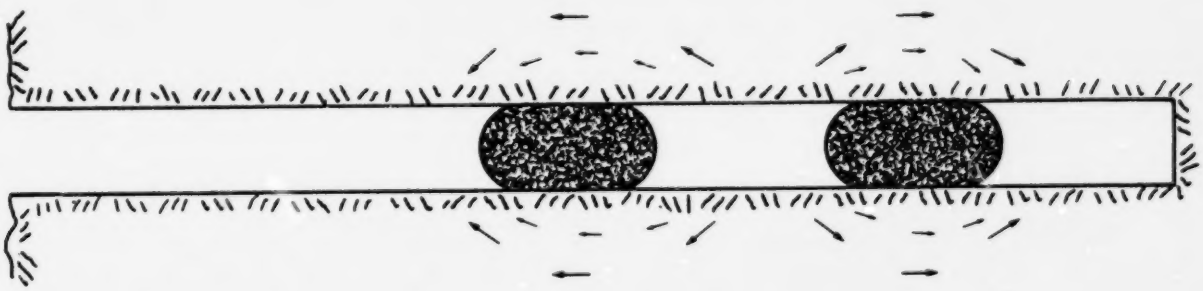

Figure 3 - Pressure loss through the intact wallrock surrounding the inflatable glands

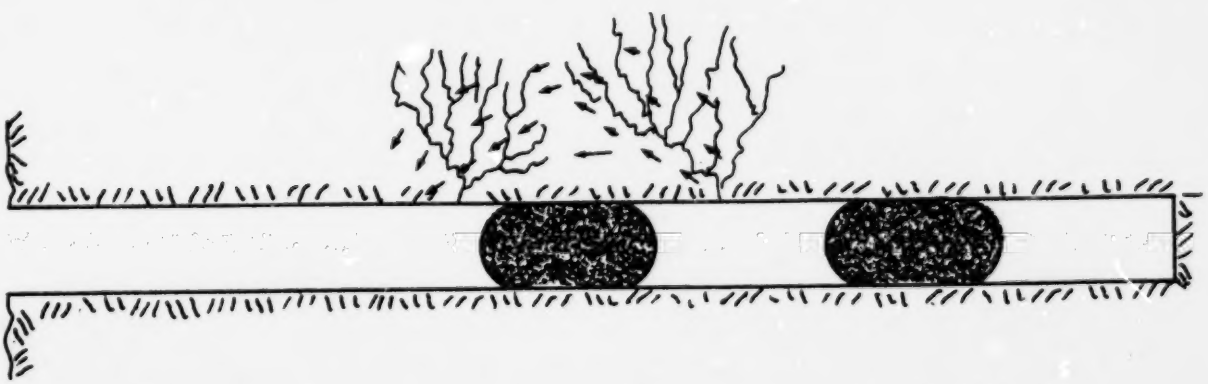

Figure 4 - Pressure loss through fractures resulting in gas migration along both the seal - strata contact and through the surrounding wallrock.

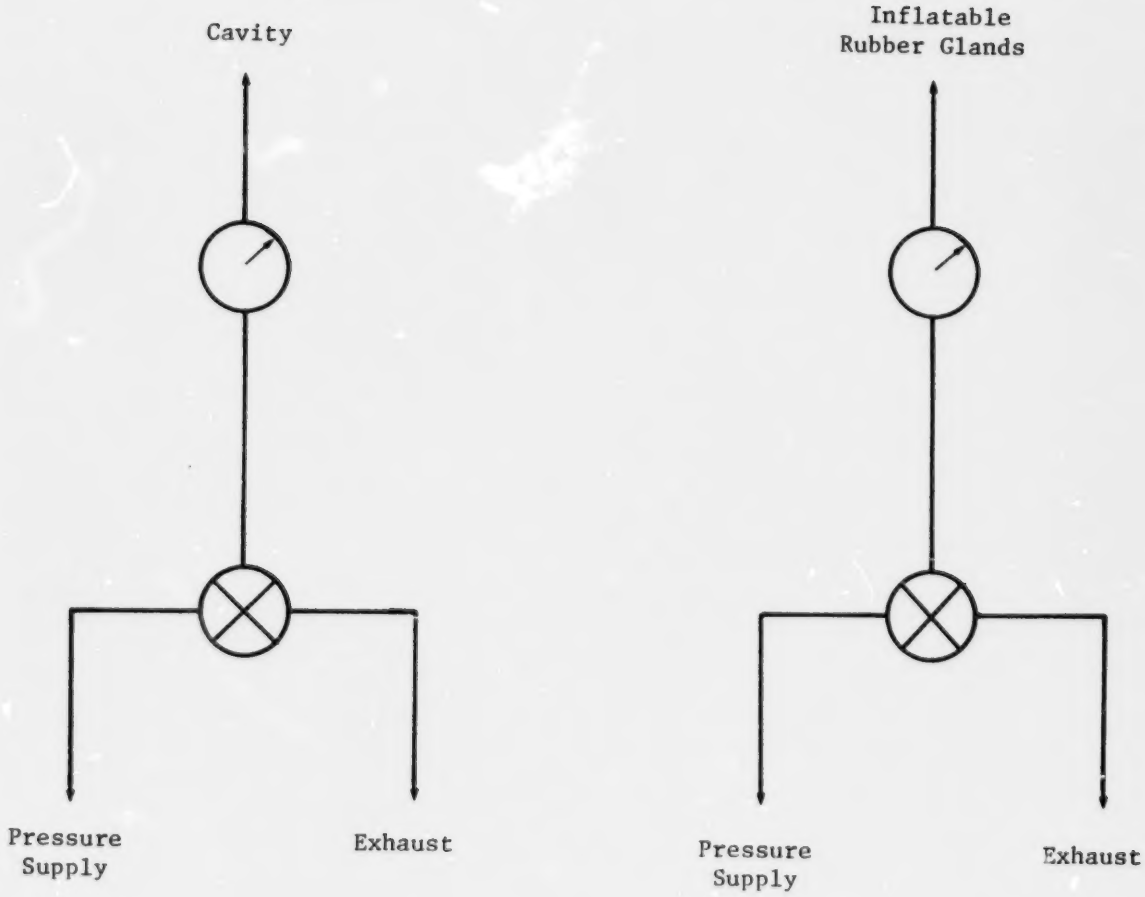

Figure 5 - Control box circuits for the packer system

its operation and this was subsequently installed underground at No. 26 Colliery. The second set was used in the laboratory in an attempt to establish the operating behaviour of the systems.

UNDERGROUND INSTALLATION AND TESTING

The packer system was installed in an NQ diamond drill hole located in a coal pillar separating the main and belt development deeps at the deepest extent of the No. 26 workings, Figure 6. The borehole was drilled parallel to the 'main deeps' at an inclination of 11 degrees to the horizontal using a Longyear 38 drill. Several sandstone horizons exhibiting the phenomena of discing which is indicative of high internal stress levels were intersected. A sandstone horizon between 18.82 m and 19.46 m (0.56 m thick) exhibiting discing was chosen as the test location. A geological description of the test section is as follows:

18.82 m - 19.46 m	Light grey sandstone. Medium grained well bedded, finely laminated with fine films of silt along the laminations. Micaceous material. Sharp contact with overlying siltstone. Polished slickensided contact. Calcite cement.
18.82 m - 19.38 m	Discing 5 mm - 13 mm thick (average 10 mm) (79 discs/metre).

Installation of the packer arrangement occurred immediately after drilling was completed and the drill rig removed from the mouth of the borehole (30 mins).

The packer was installed in the borehole using lengths of threaded iron water pipe and positioned such that the centre of the perforated steel section coincided with the centre of the previously identified sandstone horizon, 19.14 m. Once installed, the glands were inflated to 7.93 MPa (1150 psi) and the cavity left to equalize with the in situ strata pressure. As a safety precaution, a heavy duty chain was attached to the end of the water pipe protruding from the borehole and securely fastened to adjacent

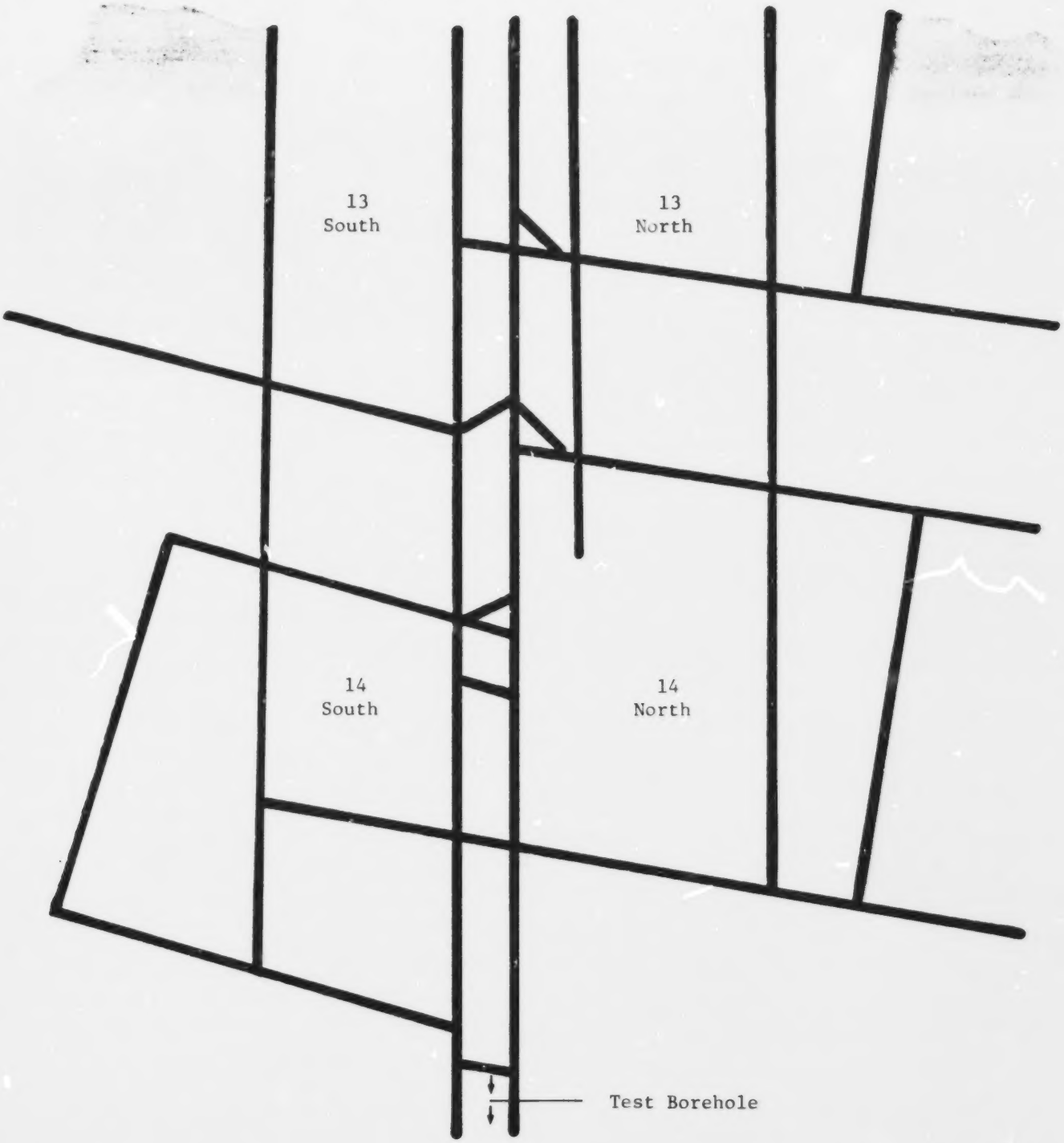

Figure 6 - Location of packer test borehole No. 26 Colliery workings

steel arches. After five days the pressure in the glands had decreased to 7.72 MPa (1120 psi) (at which level it remained for the duration of the test programme), but no discernable pressure increase had occurred in the test cavity.

A decision was then made to pressurize the test cavity with nitrogen in order to hasten equilibrium conditions. Nitrogen was injected into the cavity until a pressure of 3.45 MPa (500 psi) was reached. Within 1 hour, the cavity pressure had decreased to 3.28 MPa (475 psi) and after 24 hours to 3.17 MPa (460 psi). Eight days after initial pressurization, monitoring of the test cavity pressure revealed that it hadreached 2.62 MPa (380 psi). Unfortunately, no readings were obtained during the critical period between day 2 and day 8. After remaining at 2.62 MPa (380 psi) for 7 days (15 days after initial pressurization) the cavity pressure increased to 2.76 MPa (400 psi) by day 17. It is not known whether the increase occurred suddenly or gently over the 48 hour period between days 15 and 17. The cavity pressure remained stable at 2.76 MPa (400 psi) for the remainder of the test period (until day 45).

A plot of test cavity pressure against time is given in Figure 7, while the results are given in Appendix A.

LABORATORY TESTING OF PACKER SYSTEM

The packer system was tested under laboratory conditions in order to determine the effectiveness of the inflatable glands and assess its behaviour under operational conditions.

To simulate underground conditions, the packer arrangement was installed in a 4 m length of thick walled steel water pipe, with an internal diameter of 75 mm. Prior to installation the inside of the pipe was cleaned using compressed air and checks were made with 'suppliers' to establish whether it could withstand the internal pressures anticipated during testing.

To facilitate the safety of operating personnel, two precautions were implimentated:

1. A layer of stone dust bags were laid along the length and across the ends of the steel pipe in order to dampen any explosive failure that might occur.

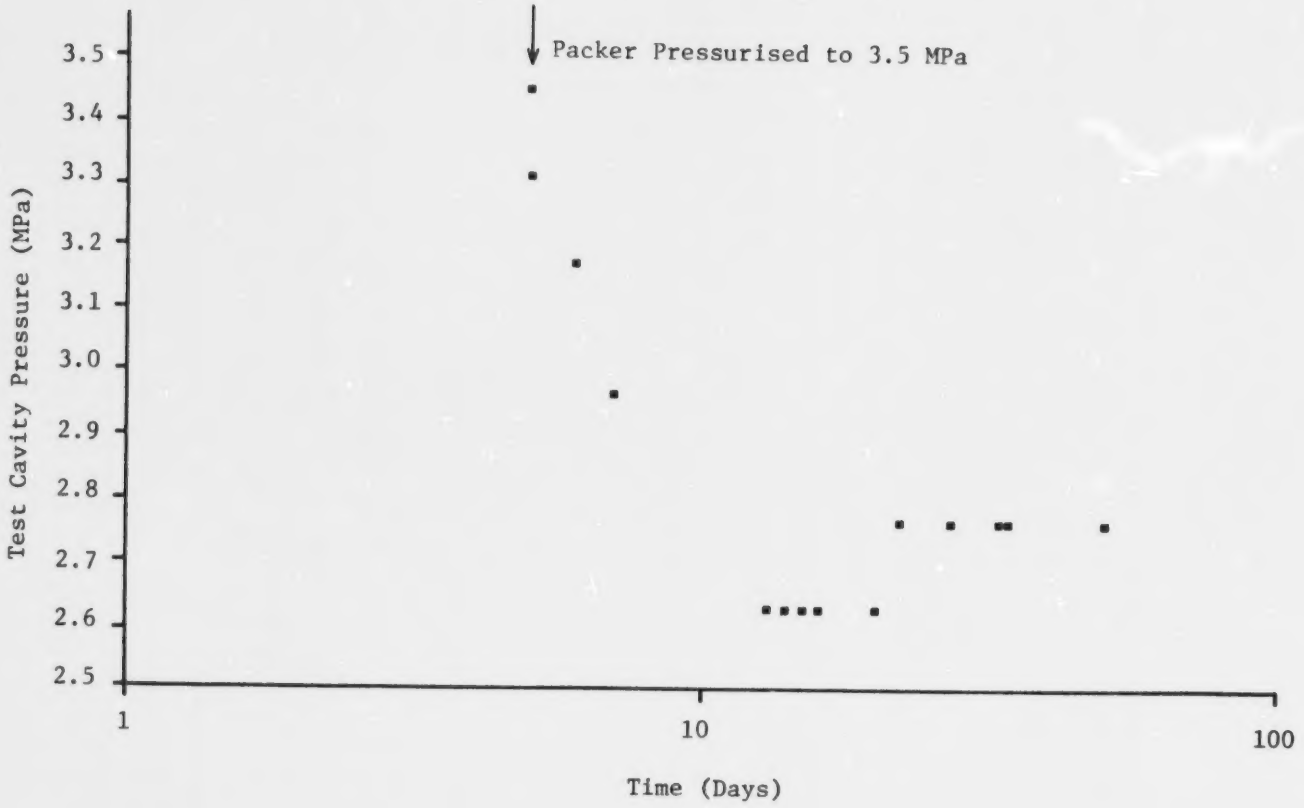

Figure 7 - Test cavity pressure against time, No. 26 Colliery borehole

2. The control box and operating personnel were located outside the room containing the apparatus during testing.

Initially, the glands were inflated to 7.93 MPa (1150 psi) and the cavity to 6.14 MPa (890 psi). The pressure decay in the cavity was then monitored over a period of five days. Pressure in the glands decreased from 7.93 MPa to 7.76 MPa during the initial 20 minutes and then remained constant for the duration of the test. A plot of the test cavity pressure decay against time is given in Figure 8, while the results are given in Appendix B.

To eliminate one potential source of pressure loss all connections in the control box were checked and found to be secure.

On March 26, 1984, a second series of laboratory tests were initiated in order to monitor packer response under 'step test' conditions. In this type of test, the cavity pressure is set to an arbitrary level, the decay rate monitored for a set period of time and then the whole procedure repeated for a series of incrementally higher values. Alternatively, the procedure can be reversed and the decay rates monitored for decreasing increments of pressure.

The glands were inflated to 7.93 MPa (1150 psi), however when the pressure in the cavity reached 6.55 MPa (950 psi) a loud bang was heard and the room became thick with dust. Subsequent inspection of the apparatus revealed that one of the gland couplings had failed causing it to separate from the remainder of the packer arrangement.

TEST CAVITY - GAS ANALYSIS

Gas samples were collected from the test cavity immediately prior to the removal of the packer arrangement from the borehole at No. 26 Colliery. The samples were analysed for the following constituents:

Methane CH_4 - 6.5%

Oxygen O_2 - 0.98%

Carbon Monoxide CO - 8 ppm

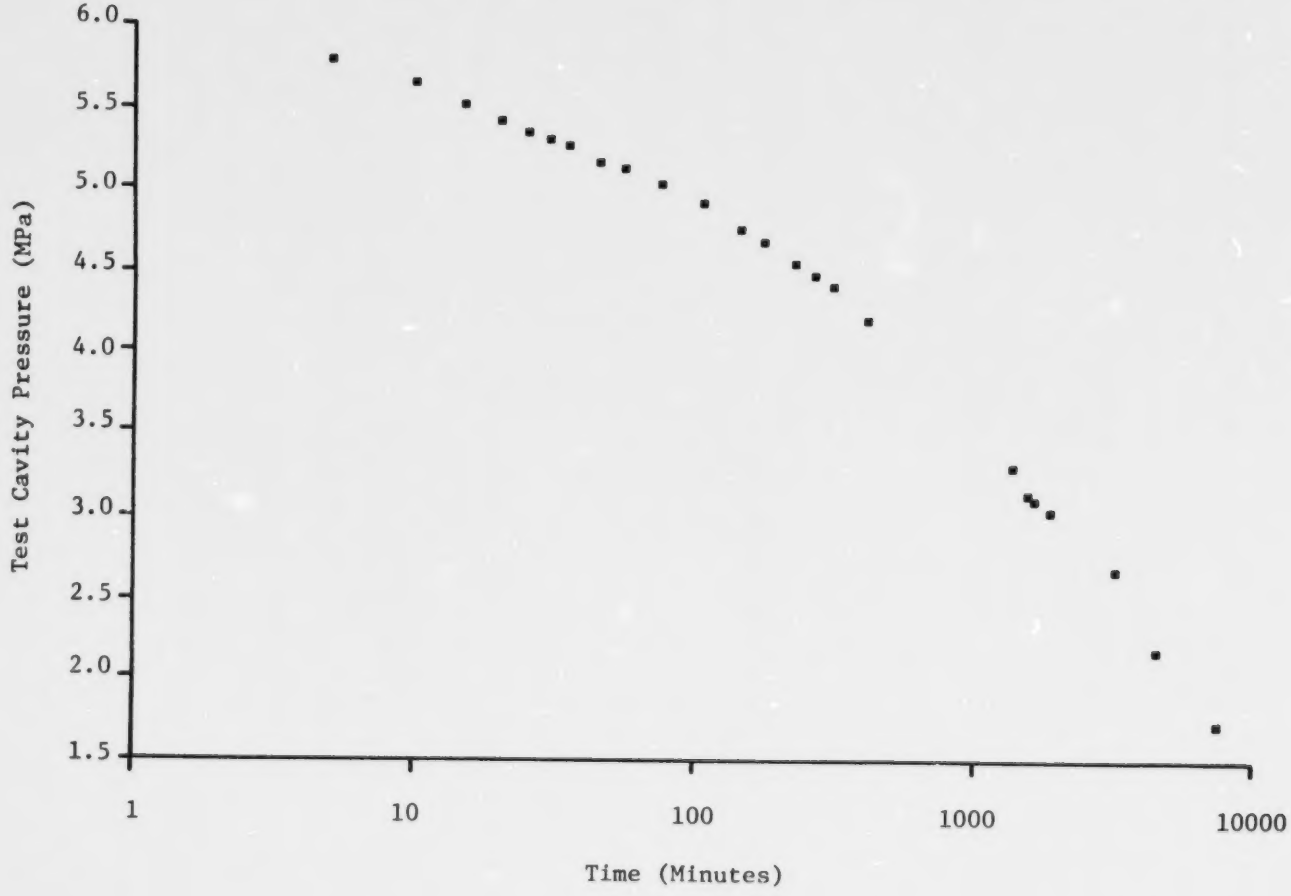

Figure 8 - Test cavity pressure against time, laboratory testing of packer system

DISCUSSION

The in situ strata gas pressure instrumentation installed at No. 26 Colliery indicates that:

1. Gas pressurization of the test cavity can reduce the time delay to reach equilibrium in such tight impermeable rock.
2. The actual in situ gas pressure at the test location equals or exceeds 2.76 MPa (400 psi).

Examination of the laboratory results suggests that gas leakage will occur around the packer glands in the underground borehole instrumentation. The equilibrium pressure of 2.76 MPa (400 psi) obtained in the test cavity may approximate quasi-steady state conditions, whereby the volume of gas lost by leakage equals the volume of gas yielded by the strata. The step change increase from 2.62 MPa to 2.76 MPa experienced in the test cavity between days 15 and 17 cannot be readily explained, although it is believed that all the instrumentation was functioning properly.

Laboratory testing has shown that the packers used in this test programme may not have a sufficient factor of safety for field and/or laboratory use. Different types of packer equipment (used by the oil industry) should be examined and evaluated before further testing.

Finally, because of the potential errors associated with the No. 26 Colliery instrumentation, it is uncertain whether the pressure of 2.76 MPa is close to or significantly lower than the actual in situ strata pressure in the sandstone. It is intended to undertake further analysis in an attempt order to determine the actual in situ strata gas pressure. Initially, standard hydrogeological techniques will be tried, possibly using the modified Theis or Thiem equations, although oil/gas industry methods may be more applicable. These results will be presented at a later date.

CONCLUSIONS

The in situ gas pressure of any strata with a low permeability can theoretically be measured using inflatable 'packer' instrumentation. However, caution should be exercised in the choice and use of such instrumentation as well as interpretation of the results. A thorough understanding of

the equipment under laboratory conditions is recommended prior to its use underground. At No. 26 Colliery, a sandstone unit associated with outburst phenomena was successfully instrumented with 'packer' equipment. However, an inferred in situ strata gas pressure of at least 2.7 MPa was only obtained after gas pressurization of the test cavity and its accuracy should be treated with caution.

ACKNOWLEDGEMENTS

The Cape Breton Coal Research Laboratory gratefully acknowledges the support and assistance of Cape Breton Development Corporation personnel who assisted in all aspects of this work. In particular, special thanks are due to the men of No. 26 Colliery who participated in the successful undertaking of this work.

REFERENCES

1. Forgeron, S. "An introduction to outburst phenomena in No. 26 colliery"; Cape Breton Development Corporation; Internal Report; January 1984.

APPENDIX A

TEST CAVITY AND PACKER PRESSURE DATA

NO. 26 COLLIERY TEST BOREHOLE

Date	Time (Days)	Packer Pressure (MPa)	Test Cavity Pressure (MPa)
9/2	-	7.93	0
10/2	-	7.72	0
13/2 (09.15)	-	7.72	0
13/2 (09.30)	-	7.72	3.45
13/2 (10.30)	-	7.72	3.28
14/2	1	7.72	3.17
15/2	2	7.72	2.97
21/2	8	7.72	2.62
22/2	9	7.72	2.62
23/2	10	7.72	2.62
24/2	11	7.72	2.62
28/2	15	7.72	2.62
1/3	17	7.72	2.76
6/3	22	7.72	2.76
12/3	28	7.72	2.76
13/3	29	7.72	2.76
29/3	45	7.72	2.76

APPENDIX B

TEST CAVITY AND PACKER PRESSURE DATA
LABORATORY TESTING

Date	Time (Minutes)	Packer Pressure (MPa)	Test Cavity Pressure (MPa)
21/3 09.45	0	7.93	6.14
09.50	5	7.93	5.79
09.55	10	7.93	5.66
10.00	15	7.93	5.52
10.05	20	7.93	5.41
10.10	25	7.76	5.34
10.15	30	7.76	5.31
10.20	35	7.76	5.28
10.30	45	7.76	5.17
10.40	55	7.76	5.14
11.00	75	7.76	5.04
11.30	105	7.76	4.93
12.10	145	7.76	4.76
12.40	175	7.76	4.69
13.30	225	7.76	4.55
14.10	265	7.76	4.48
14.50	305	7.76	4.41
16.35	410	7.76	4.21
22/3 09.00	1395	7.76	3.31
11.45	1560	7.76	3.14
13.10	1645	7.76	3.10
16.00	1815	7.76	3.03
23/3 11.35	2990	7.76	2.69
24/3 13.00	4500	7.76	2.17
26/3 09.30	7200	7.76	1.72